PORTABLE OSCILLOSCOPE TECHNIQUE FOR DETECTING DORMANCY IN NURSERY STOCK

Robert B. Ferguson, Russell A. Ryker, and Edward D. Ballard

USDA Forest Service General Technical Report INT-26, 1975
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Ogden, Utah 84401

USDA Forest Service
General Technical Report INT-26
1975

PORTABLE OSCILLOSCOPE TECHNIQUE FOR DETECTING DORMANCY IN NURSERY STOCK

Robert B. Ferguson, Russell A. Ryker,
and Edward D. Ballard

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Forest Service
U.S. Department of Agriculture
Ogden, Utah 84401

THE AUTHORS

ROBERT B. FERGUSON is Associate Wildlife Biologist assigned to the Intermountain Station's Shrub Improvement and Revegetation research work unit at Boise, Idaho. He received his bachelor of science degree in Forestry from West Virginia University in 1953, and his master's degree in Wildlife Management from Utah State University in 1955. His primary assignment since 1956 has been the study of artificial revegetation of deer winter ranges in southern Idaho.

RUSSELL A. RYKER is a Research Silviculturist for the Intermountain Station at Boise, Idaho. He received his B.S. (Forestry) degree in 1954 and M.S. (Forestry) degree in 1962 from the University of Missouri. From 1956 to 1963 he conducted research in the silviculture of central hardwoods for the Central States Station. From 1963 to 1967, he was with the silviculture project at Moscow, Idaho.

EDWARD D. BALLARD is an Electronics Technician for the Boise National Forest, at Boise, Idaho. He received his electronics training from the U.S. Air Force, and began his work for the Forest Service in 1965 at Missoula, Montana, where he assisted with Project Fire Scan. He has been at Boise since 1966.

CONTENTS

ABSTRACT

The proper timing for lifting nursery-grown planting stock is an important factor in the ultimate success of revegetation efforts on forest and range lands. This report describes a portable oscilloscope technique used to determine the level of activity or dormancy of nursery stock and plants in the field. The equipment includes a battery-powered oscilloscope and square wave signal generator, both commercially available, and a specialized electrode that must be constructed. A variety of plant species, including conifers and deciduous trees and shrubs, were monitored during all seasons of the year. Oscilloscopic wave form appeared to be related to periods of plant dormancy and activity. Certain similarities in wave form-seasonal relations were observed in related groups of plant species. The report describes the equipment used in detail, and suggests several potential uses to nurserymen and research workers.

INTRODUCTION

One of the primary factors affecting success in transplanting trees and shrubs is the degree of disturbance of the plant's physiological functions. When bare-root nursery stock is used for planting in the forest or on the range it has generally been believed that the best time to transplant is when the plants are dormant. Toumey and Korstian (1947) state that "planting should be done after growth ceases in autumn and before growth starts in spring."

To date, nurserymen have had to estimate the degree of dormancy of nursery stock by visual signs such as the development of terminal buds in autumn and the swelling and opening of buds in the spring. The proper timing for lifting nursery stock for field planting could be more precisely determined if a reliable method for monitoring physiological activity was available.

Wanek (1971) tried to assess the degree of dormancy by the shape of an oscilloscope trace when a square wave electrical pulse was applied to a Douglas-fir needle. He obtained differences in trace shape that he felt might indicate life or death of plant tissue, as well as a trace shape that he thought indicated dormant tissue.

Zaerr (1972) evaluated oscilloscope trace shape as an indication of injury or death of plant tissue following exposure to freezing, steaming, or treatment with an herbicide.

Following correspondence with Wanek and Zaerr in early 1972, we conducted additional research to determine whether a reliable technique could be developed for determining plant dormancy, utilizing portable oscilloscope equipment. This report is intended primarily as a guide for others in obtaining and using the portable oscilloscope and square wave generator. In addition, it summarizes our observations on numerous plant species.

FALL LIFTING APPLICATION

The portable oscilloscope technique has been used since the autumn of 1974 as an aid in determining dormancy of coniferous planting stock before fall lifting at Lucky Peak Nursery near Boise, Idaho. Although no research has been done to determine whether planting success will be increased as a result of using the oscilloscope, it is hoped that the technique will improve the timing of fall lifting.

Our experience is that appearance on the oscilloscope screen of the square wave pattern believed to indicate full dormancy does not correspond with complete development of winter buds. The square wave appears 2 or more weeks after winter buds are fully developed. The time lag seems to vary with the year, species, seedling age, seedling density in beds, and watering schedules.

EQUIPMENT

Equipment to provide readings of physiological activity in plant tissue includes an oscilloscope, square wave generator, electrode, and connecting cables. For practical field use, the system must be lightweight and include its own power sources.

The system described here can be assembled in a suitable carrying case for field use. We used an attache case 18 inches long, 13 inches wide, and 7 inches deep (fig. 1). In this arrangement the components and case weigh about 15 pounds.

Portable Oscilloscope

For all our experiments, we used the Tektronix Model 211 oscilloscope (fig. 2). The unit may be obtained from Tektronix Inc., 14150 S. W. Karl Brown Dr., Beaverton, Oregon 97005. Federal agency personnel may refer to FSC Group 66, Part II, Section G, Contract No. GS-005-13175.

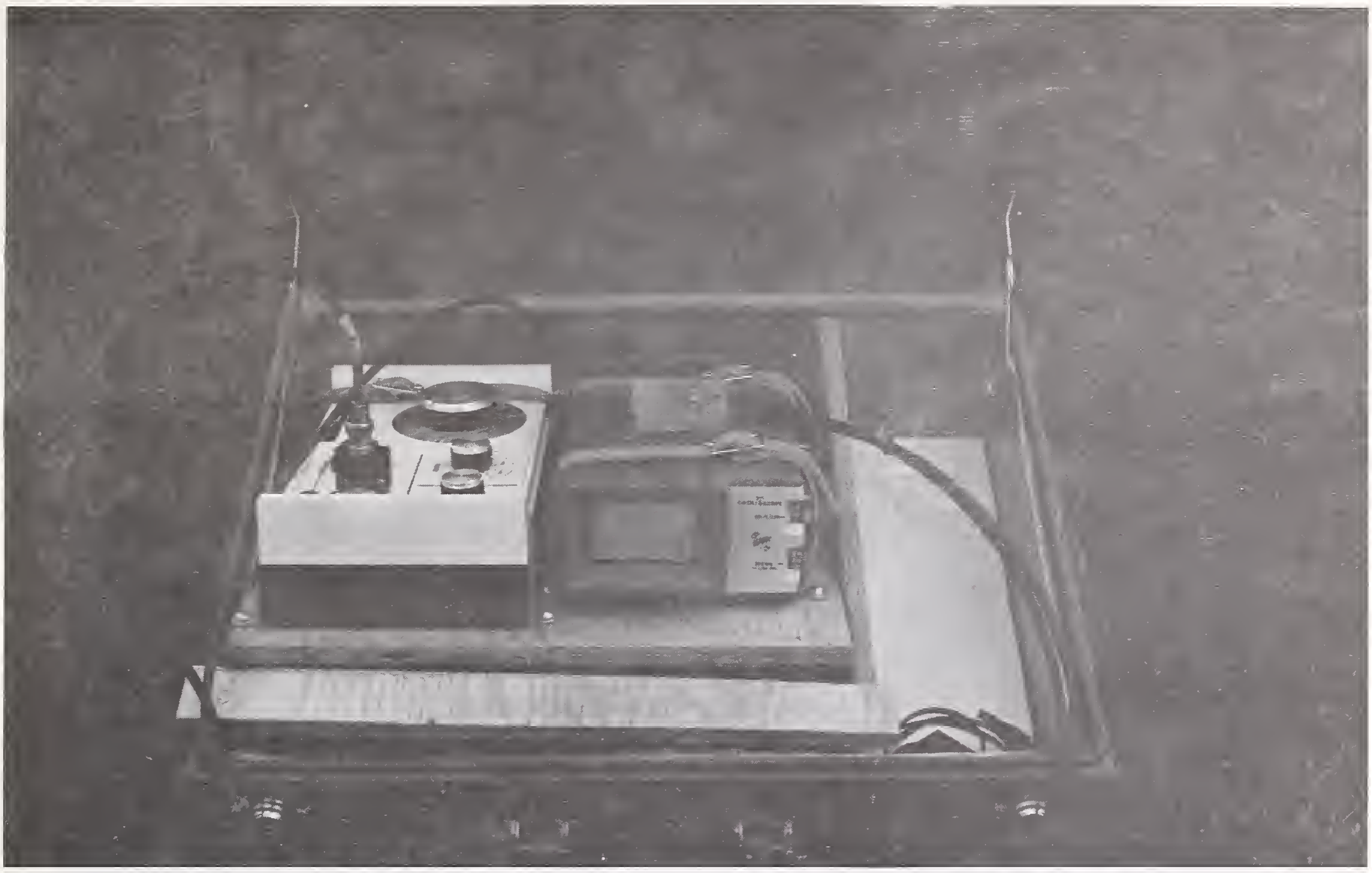


Figure 1.--Portable oscilloscope and square wave generator assembled in a single carrying case for field use.

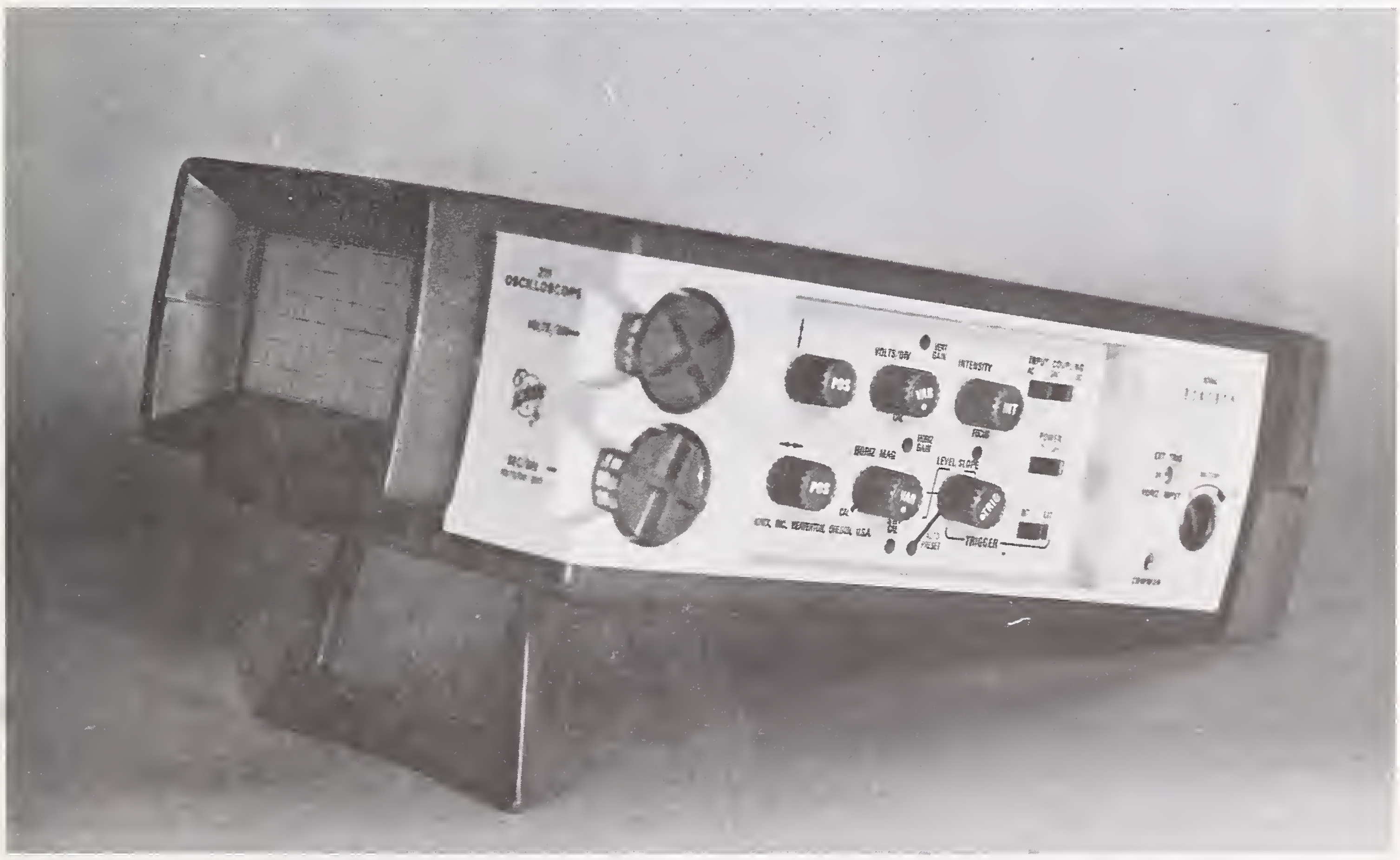


Figure 2.--The Tektronix Model 211 battery-operated, portable oscilloscope.

Portable Square Wave Generator

Our original battery-powered square wave generator was constructed by Edward D. Ballard. The Wavetek Model 30 generator (fig. 3) performs the same function, is commercially available, and is somewhat more versatile.

The Model 30 is manufactured by Wavetek, P. O. Box 651, San Diego, California 92112. The manufacturer will supply a list of distributors.

To familiarize readers with easily available equipment, the connection and control setting instructions in this report apply to the Model 30 generator. The research observations reported here were made with a system including the unit constructed by Ballard.

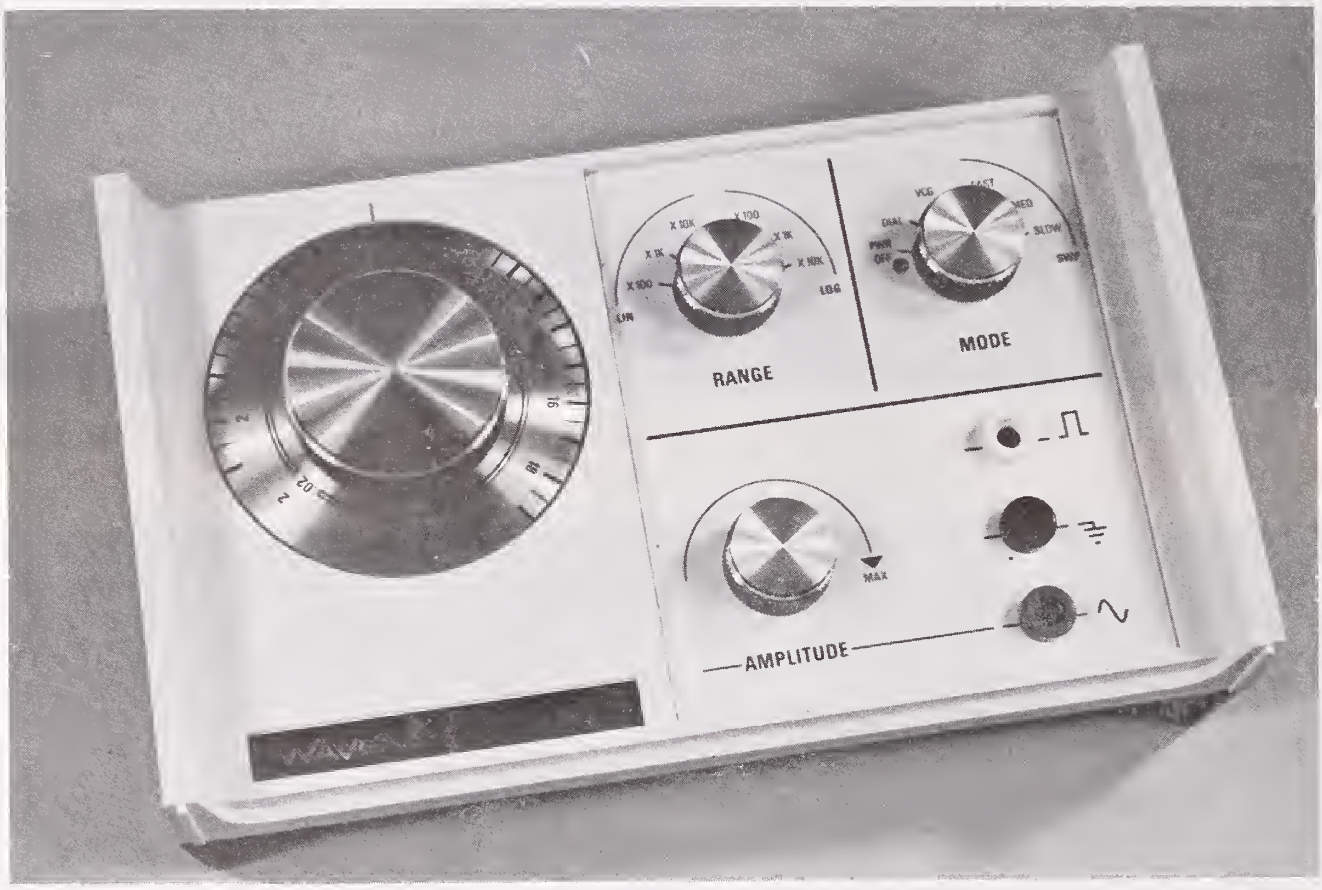


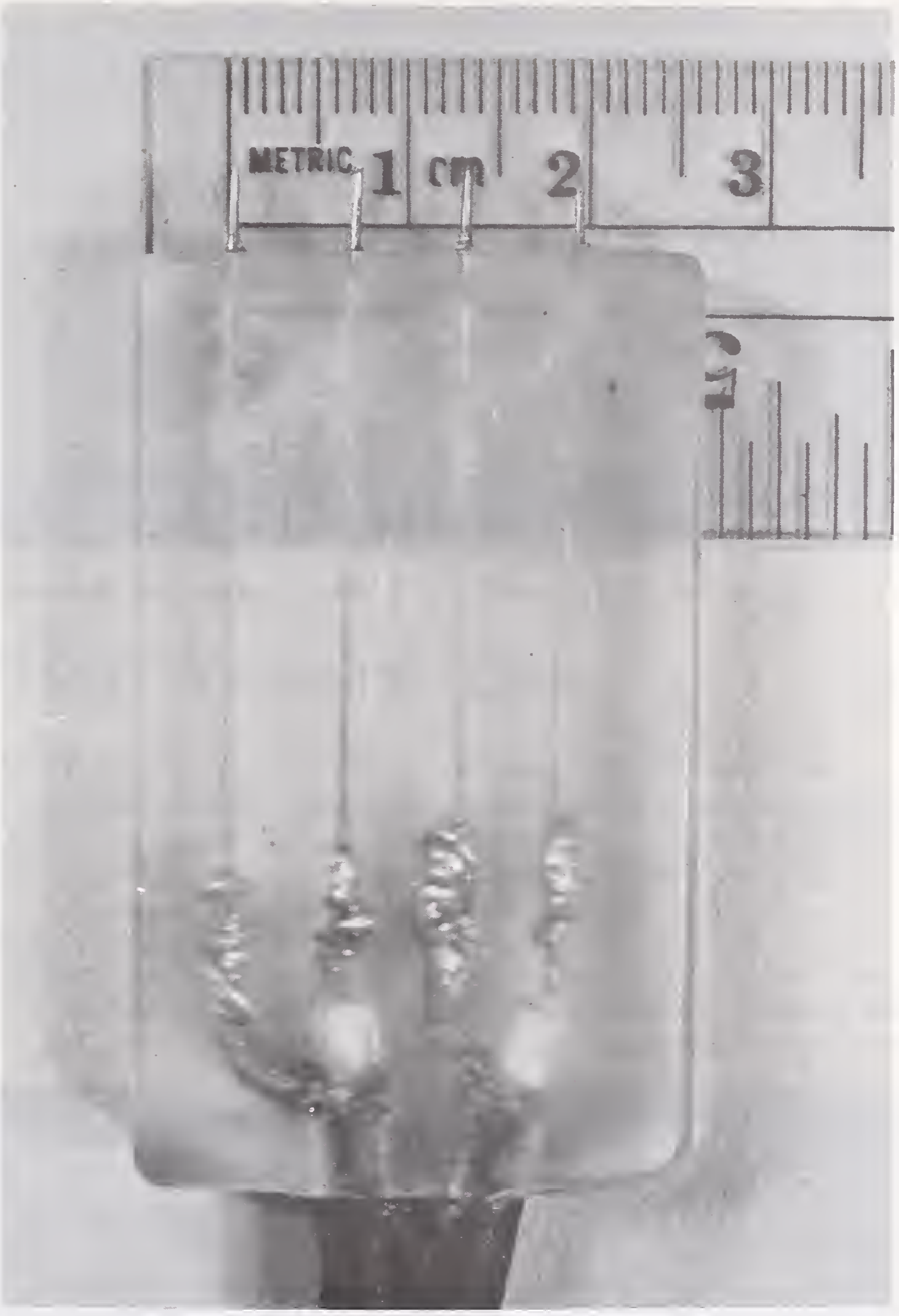
Figure 3.--The Wavetek Model 30 battery-operated square wave generator.

Electrode

An electrode must be constructed to transmit the square wave electrical pulse through plant tissue.

Our electrode (fig. 4) consists of four stainless steel surgical needles embedded in clear plastic and connected to two 4-foot coaxial cables. Electrode construction details are given in the appendix.

Figure 4.--Electrode used to transmit square wave signal through plant tissue. Stainless steel needles are spaced about 7 mm apart.



PROCEDURE

Oscilloscope readings can be taken in less than one-half minute per plant after units are properly connected and controls are set. Before starting the procedure, set controls on the side panel of the oscilloscope (fig. 5):

Control	*Setting*
VOLTS/DIV	Calibrate (CAL)
HORIZ MAG	Calibrate (CAL)
TRIGGER (LEVEL/SLOPE)	Auto preset
TRIGGER (INT-EXT)	INT
INPUT COUPLING	AC

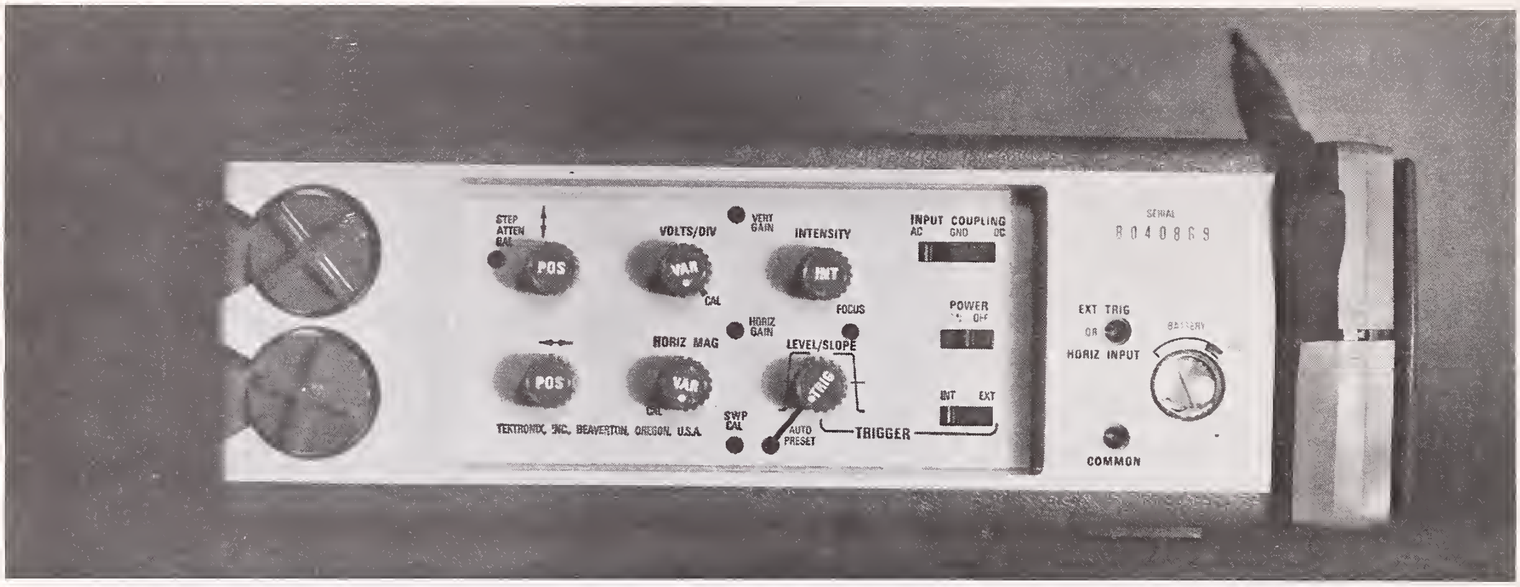


Figure 5.--Side panel of controls for the Tektronix Model 211 oscilloscope.

Set the SEC/DIV control on the front of the oscilloscope at 0.2 m and turn the frequency scale dial of the generator to 8.5 and the range switch to X100. Then:

1. Turn on the oscilloscope.

2. Insert the electrode needles well into the plant tissue (just below the terminal bud for nursery stock; fig. 6). If stem or twig diameter is small enough, push the needles completely through. After the needles are firmly embedded, do not touch them because trace shape will be affected.

Figure 6.--Electrode needles embedded in nursery seedling for reading.

3. Turn on the square wave generator. Waiting until after the electrode needles are embedded in the plant minimizes battery drain.

4. Adjust other oscilloscope controls as necessary to clearly view the trace. Frequently, the VOLTS/DIV control on the front of the oscilloscope will require adjustment to increase the amplitude to near full-screen height. To avoid battery drain, set the INTENSITY control only as high as necessary to provide a good image. Adjust the position controls to center the trace.

Visibility of the trace on the screen can be improved when using the system outdoors by attaching the plastic shade provided with the oscilloscope. We have recorded signal traces by photographing the screen with a 35 mm camera using standard black and white film. The photograph may include VOLTS/DIV and SEC/DIV control settings, which may be useful if the same plant is tested later.

INTERPRETING WAVE TRACES

Figure 7 shows drawings of the general forms of oscilloscope traces that we interpret to indicate active, fully dormant, and dead tissue. The square wave will pass through the tissue essentially unchanged, though decreased in amplitude, if the tissue is dormant. If the tissue is active, the wave form will be peaked on the left edge and decrease in height toward the right. Dead plant tissue, whether wet (as when boiled) or dry, exhibits a sawtooth wave form on the oscilloscope.

In most plant species we have studied, the changes from dormancy to activity in the spring and from activity to dormancy in the fall are gradual. The leading (left) edge of the square wave shows only a small peak during the transition periods. We have observed considerable variation in the length of transition periods, which may be due to species differences or to variations in microenvironment.

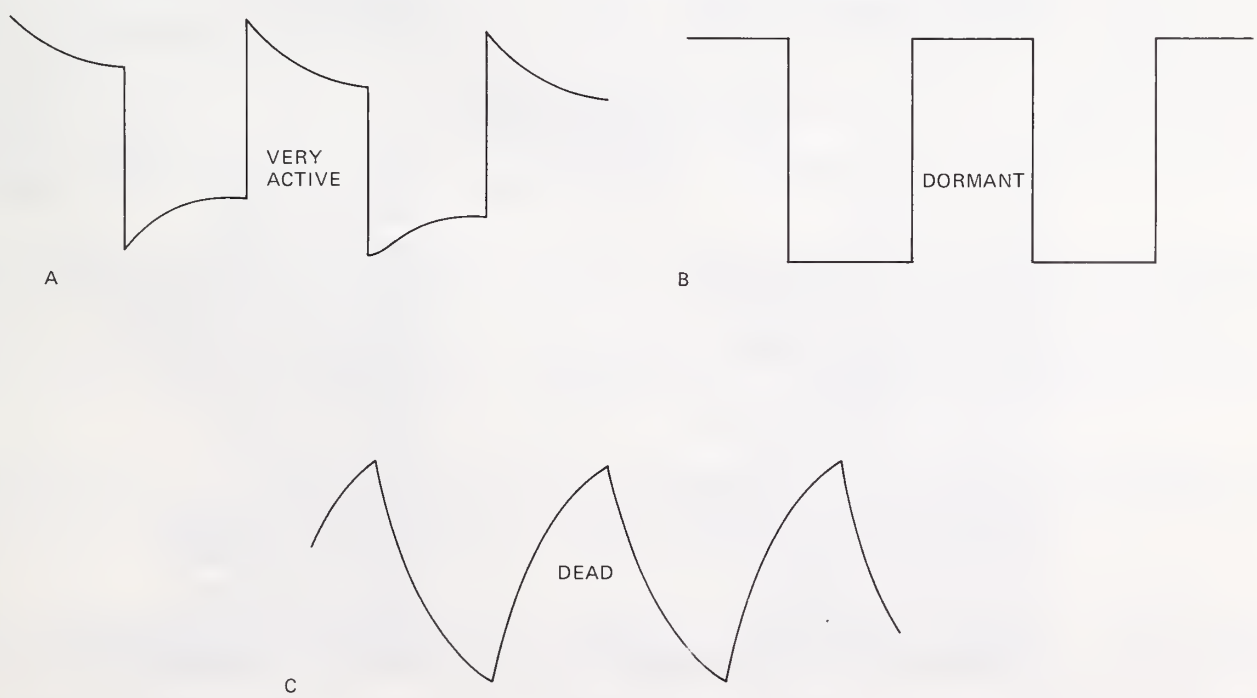


Figure 7.--Patterns of oscilloscope traces that indicate (A) active, (B) dormant, and (C) dead tissue.

RESEARCH

Test Procedures

In mid-October 1972, six tree species and one shrub species were chosen for periodic testing with the portable oscilloscope. These plants were located at the Lucky Peak Nursery (elevation 3,200 feet). Plants were tagged so that readings could be made on the same specimens on each observation date.

In March 1973, a number of native tree and shrub species were selected for observation. These plants were located in Boise County along State Highway 21, beginning at an elevation of 6,200 feet near Mores Creek Summit, and ending at 4,500 feet elevation at Fan Creek, 8 miles north of Idaho City. Plant species selected at each location were:

LUCKY PEAK NURSERY

Larix occidentalis	Western larch
Picea engelmannii	Engelmann spruce
Pinus contorta	Lodgepole pine
Pinus ponderosa	Ponderosa pine
Populus deltoides	Cottonwood
Pseudotsuga menziesii	Douglas-fir
Purshia tridentata	Antelope bitterbrush

BOISE COUNTY TRANSECT

Abies lasiocarpa	Subalpine fir
Acer glabrum	Douglas maple
Alnus incana	Mountain alder
Amelanchier alnifolia	Saskatoon serviceberry
Ceanothus velutinus	Snowbrush ceanothus
Cornus stolonifera	Redosier dogwood
Pinus ponderosa	Ponderosa pine
Populus tremuloides	Quaking aspen
Prunus emarginata	Bitter cherry
Pseudotsuga menziesii	Douglas-fir
Rhamnus purshiana	Cascara buckthorn
Salix scouleriana	Scouler willow
Sambucus cerulea	Blue elderberry
Sorbus scopulina	Greene's mountain ash
Symphoricarpos oreophilus	Mountain snowberry

Between January and May 1973, several species of trees and shrubs were tested in the vicinity of the Intermountain Station's Forestry Sciences Laboratory in Boise (elevation 2,700 feet).

Using the portable equipment, readings were taken of intact stem tissue. During the autumn, winter, and spring of 1972-1973 the readings were taken on terminal or lateral twig growth of the 1972 growing season. As soon as new growth had elongated enough in 1973, it was usually used for the reading.

The needles of the probe were pushed firmly into the twig (entirely through if the twig was small enough). With the oscilloscope turned on, the square wave generator was set at 1 volt output and the generator switched on. The horizontal sweep adjustment of the oscilloscope was set at 0.2 millisecond per division, and the vertical deflection control tuned to obtain approximately full scale amplitude. A 35 mm camera was used to photograph each trace display. The entire procedure could easily be completed in half a minute.

We found that only a single reading was necessary on each plant, since similarly shaped traces were obtained whenever the probe needles were embedded in similar positions of the plant. For example, readings were similar when taken near the tip of the youngest woody tissue.

Three plants of each species sampled at the nursery were read. At other locations only one reading was usually taken for each species, though occasionally several readings were made for verification. From early April to October 1973, some phenological notations were recorded for most species on the dates that readings were obtained.

Results and Discussion

At the beginning of the field study in October 1972, five of the seven species located at the nursery exhibited trace shapes similar to those illustrated by oak (*Quercus* sp.) and bitterbrush in figure 8. We interpret this as indicating that the portion of the plant into which the probe has been inserted has become dormant. The remaining two species, Douglas-fir and western larch, exhibited trace shapes having a slightly raised leading edge (illustrated by arborvitae in figure 8), indicating less impedance of the high frequencies. We interpret this to indicate continued activity of the plant tissue being tested. By October 31 and November 14, western larch and Douglas-fir, respectively, exhibited the dormant trace. There was little variation in trace shape between plants of the same species.

Through the months of November, December, and January all species at the nursery location remained dormant. However, at the lower elevation of the City of Boise a horticultural variety of mockorange (*Philadelphus* sp.) exhibited a conspicuously raised (peaked) leading edge on January 22. This was the only species showing this trace shape out of 14 species of trees and shrubs checked on that date in Boise.

On February 14, lodgepole pine and western larch at the nursery exhibited slightly peaked traces. The larch was lifted from the seedbeds before any further observations could be made. Douglas-fir indicated slight activity on February 21.

On February 26 only three of the 14 species sampled at Boise were slightly active: mockorange, Pfitzer juniper (*Juniperus chinensis pfitzeriana* Spaeth.), and golden currant (*Ribes aureum* Pursh). By March 20 only a species of arborvitae (*Thuja orientalis* L.) had joined these three species in exhibiting a peaked trace. Other deciduous tree and shrub species, as well as Colorado blue spruce (*Picea pungens* Engelm.) still showed square or slightly rounded traces.

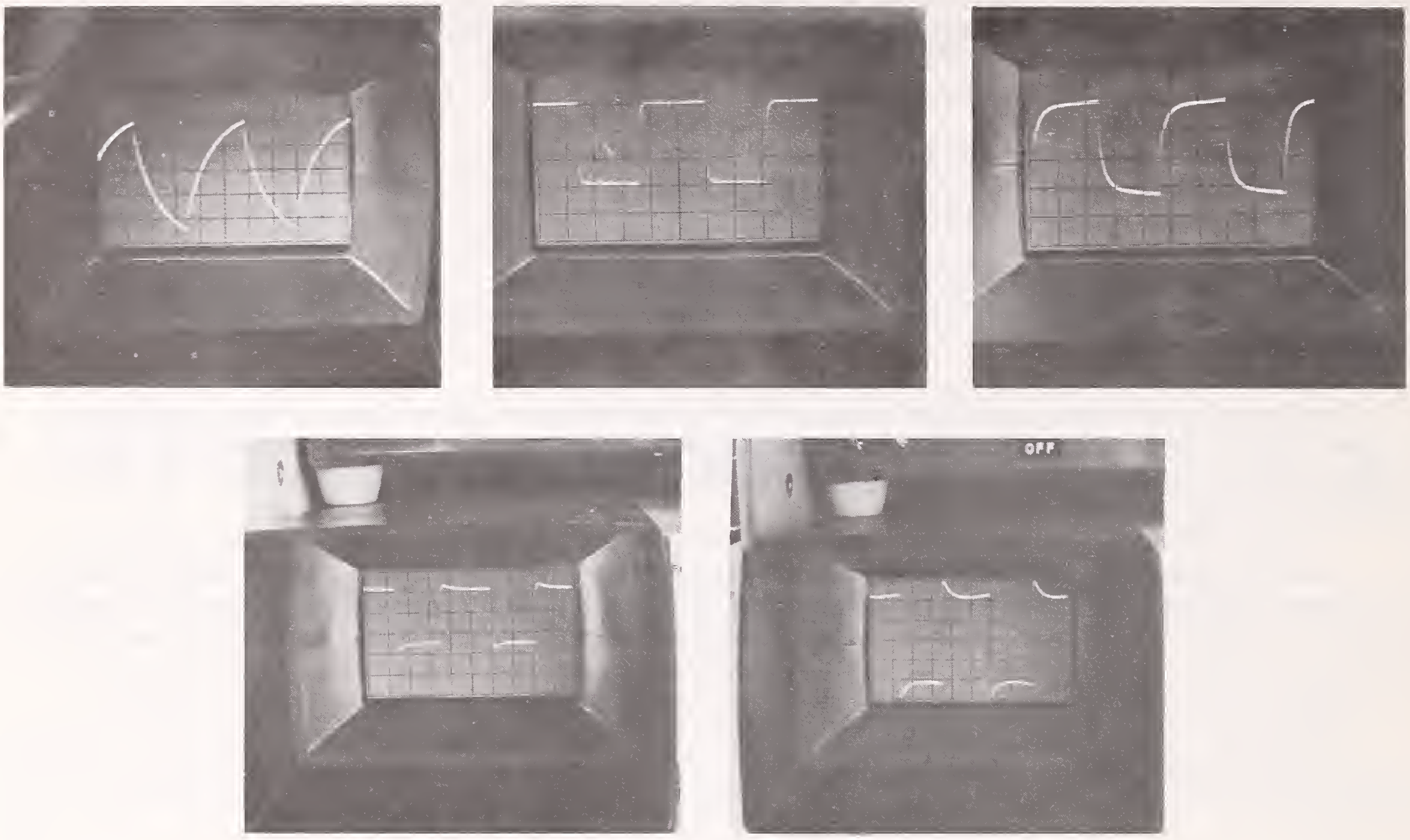


Figure 8.--Oscilloscope traces obtained when a square wave signal is transmitted through dead plant tissue (upper left), dormant plant tissue (oak, upper center; and bitterbrush, upper right), slightly active plant tissue (arborvitae, lower left), and active plant tissue (barberry, lower right). The trace indicating dormancy may vary from nearly square to a form more rounded on the leading edge.

On March 23 we began observations at the Boise County transect. Only Douglas-fir exhibited a slightly peaked trace (while at the lower elevation nursery site, ponderosa pine and Douglas-fir now showed slight activity). By April 4, both Douglas-fir and ponderosa pine exhibited an increasingly greater peak on the leading edge of the trace (similar to the illustration for barberry (*Berberis* sp.) in figure 8). On April 19 only Douglas-fir showed a peaked trace along the Boise County transect, and Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) had become active at the nursery. By May 4, subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) was active at 6,200 feet elevation and cottonwood (*Populus deltoides* Marsh.) was active at the nursery.

The sequence continued into the summer until all species exhibited a peaked trace shape. Figure 9 presents the approximate length of the dormant and active periods for several species selected from those sampled during 1972 and 1973. Local climatic variation probably affects the length of the dormant period for most plant species.

Electrical Circuit Responses

Oscilloscopes and square wave generators are routinely used in electronic repair shops to test the response of electrical circuits. The usefulness of the square wave for circuit testing lies in the nature of the wave form. The square wave is a complex wave form composed of many sine waves--a fundamental frequency and all its harmonics. Therefore, it permits in one operation, testing of circuit response to a wide range of frequencies.

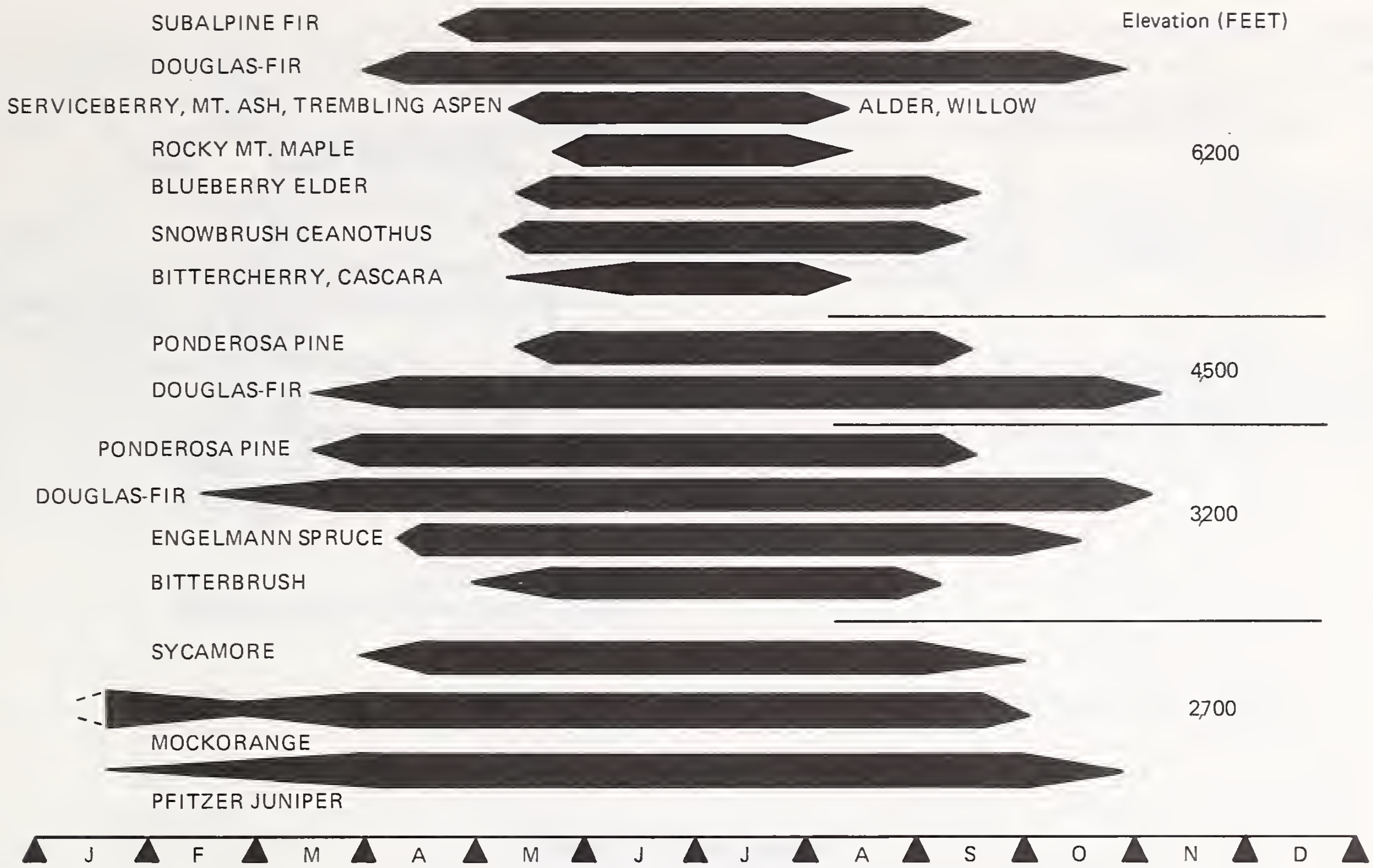


Figure 9.--Length of active period for selected species of trees and shrubs at four different elevations.

In assessing the degree of a plant's physiological activity with this equipment, we are testing the response characteristics of an electrical circuit in the plant. The section of twig between the electrodes can be represented by an electrical circuit consisting of elements of resistance and capacitance connected in series and parallel (DePlater and Greenham 1959).

Hayden and others (1969) proposed a model for the electrical circuit in plants. Its essential components are cell wall resistance, cytoplasm resistance, and cell membrane resistance and capacitance (fig. 10). Changes in the physiological status of the plant presumably change capacitance at the cell membrane, and are reflected in changes in wave form on the oscilloscope. Resistance is independent of frequency, while capacitance and frequency are related as shown in the formula for capacitive reactance (X_c):

$$X_c = \frac{1}{2\pi fC}$$

The formula shows that as capacitance and frequency increase, the opposition to current flow decreases. This effect shows up on the oscilloscope as a peak at the left edge of the square wave (fig. 7a). This occurs at the time plants are active. If capacitance should decrease, the opposition to current flow would increase and the wave form would gradually return to the square wave shape (fig. 7B). This seems to occur at the time plants enter the dormant state. At death, capacitance is lost resulting in high frequency cutoff. This is distinguished by a sawtooth wave form (fig. 7C). We do not know what changes in the plant result in an increase or decrease in capacitance, but changes in cell membrane thickness and permeability are suspected factors.

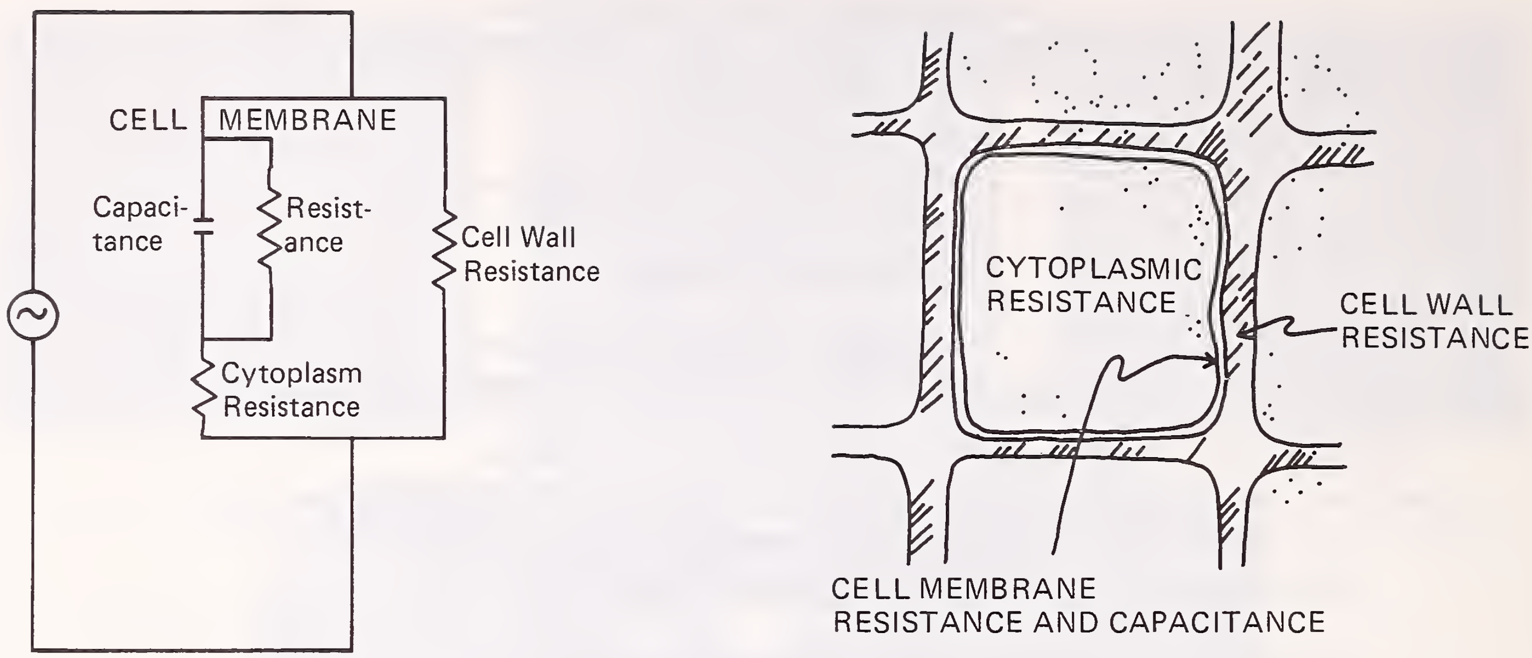


Figure 10.--An electrical model proposed by Hayden and others (1969).

Research Needs

We have observed a tendency toward similarity in wave form between related species. For example, nearly all species of the family Pinaceae exhibited dormant season wave forms having no slope to the left. The one exception was a nursery-grown western larch seedling. These same species seldom exhibit an active season wave form that slopes to the left before peaking. However, the majority of deciduous shrub species exhibited wave forms that sloped to some degree, both during the dormant and active seasons. More intensive observations of many plant species are needed to determine how much consistency in wave form exists in specific groups of plants.

We have assumed that the increase or decrease in the impedance of the high frequency components of the square wave signal reflect changes in electrical characteristics that occur at the time the plant enters or leaves dormancy. We still need to learn exactly what is happening in the plant tissues at the time we obtain various wave forms on the oscilloscope screen. Has growth (cell division and expansion) stopped when we can no longer detect any peak of the square wave? What effect does moisture content of the plant tissue have on wave form?

POTENTIAL USES

It is likely that additional work with this type of electronic equipment will reveal a number of ways in which it can be used to reveal changes in the physiological activity of plant tissue. If the probe could be miniaturized, the activity of smaller plant parts such as buds, conifer needles, or the vascular systems of the leaves of deciduous trees and shrubs could be monitored.

The portable oscilloscope and square wave generator might also be used to evaluate the relative frost hardiness or cold tolerance of biotypes within a species, or between different plant species. Possibly, the effect of other environmental influences (such as heat or drought) could be evaluated through oscilloscope readings.

This technique might also be valuable in the examination of nursery stock during storage to assess the effects of storage conditions. It also may be useful to determine activity in target and nontarget plants in vegetation control projects where growth stage is critical in achieving success.

The advantage of utilizing interpretations of changes in the square wave shape to assess physiological status of plant tissue is that factors such as tissue temperature and depth of penetration of the electrodes do not seem to significantly affect wave form, while impedance measurements such as discussed by Evert (1973) and Glerum and Krenciglowa (1970) are influenced by such factors.

PUBLICATIONS CITED

DePlater, C. V., and C. G. Greenham.
1959. A wide-range a.c. bridge for determining injury and death. Plant Physiol. 34:661-667.

Evert, D. R.
1973. Factors affecting electrical impedance of internodal stem sections. Plant Physiol. 51:478-480.

Glerum, C., and E. M. Krenciglowa.
1970. The dependence of electrical impedance of woody stems on various frequencies and tissues. Can. J. Bot. 48:2187-2192.

Hayden, R. I., C. A. Moyse, F. W. Calder, D. P. Crawford, and D. S. Fensom.
1969. Electrical impedance studies on potato and alfalfa tissue. J. Exp. Bot. 20(63):177-200.

Toumey, J. W., and C. F. Korstian.
1947. Foundations of silviculture; upon an ecological basis. 2nd ed., rev. 468 p. John Wiley & Sons, Inc., New York, N. Y.

W[illegible]k, J.
1971. *In* Electronics now being used to "bug" Doug-fir trees. The Forest Log 41(5):3. State of Oregon, Dep. For.

Zaerr, J. B.
1972. Early detection of dead plant tissue. Can. J. For. Res. 2(2):105-110.

APPENDIX

Equipment Development and Details

Portable Oscilloscope

The Tektronix Model 211 oscilloscope is battery-operated, 3.0 inches high, 5.2 inches wide, and 8.9 inches long. The Model 211 is a triggered, single channel, 500 kHz instrument using all solid state and integrated circuit components except for the cathode ray tube.

Vertical deflection is calibrated from 1 millivolt to 50 volts per division. For the range of 10 millivolts to 50 volts, the bandwidth is from DC to at least 500 kHz. Input resistance is approximately 1 megohm. Input capacitance is approximately 130 picofarads. Horizontal deflection is calibrated from 200 milliseconds to 5 microseconds per division.

Portable Square Wave Generator

Our original battery-operated square wave generator was constructed to generate a square wave signal at a fixed frequency of 1,000 Hz, ±20 percent, with an amplitude variable from 0 to 15 V. This signal generator was 5.0 inches wide, 3.4 inches high, and 6.0 inches long, as viewed from the face. It was strapped to the top of the oscilloscope (fig. 11), and the two instruments were carried in a specially made leather carrying case. All tests reported in this paper were made with this generator.

The Wavetek Model 30 (fig. 3) is a battery-operated, self-sweeping audio function generator. Frequency ranges are 2 Hz to 2 kHz, 20 Hz to 20 kHz, and 200 Hz to 200 kHz. The generator is supplied with a conventional 9-V transistor battery, which will operate the generator for a full 8-hr day. A rechargeable nickel-cadmium battery and charger can be supplied as an option, which gives unlimited operation time when left connected to the line voltage.

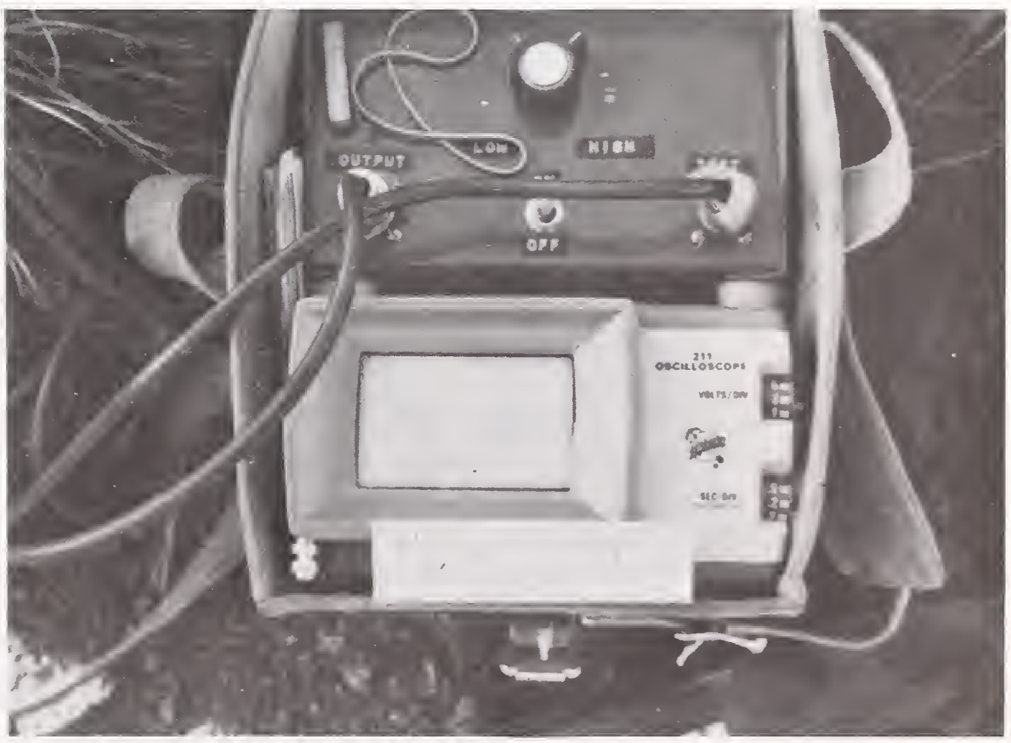


Figure 11.--Portable oscilloscope and square wave generator assembled in a home-made, leather carrying case. The square wave generator shown here was constructed by E. D. Ballard.

Electrode

Zaerr's electrode was constructed of four silver pins 0.64 mm in diameter arranged in a straight line. The pins were coated with silver chloride, spaced 2 mm apart, and inserted in a plastic block so that only the tips protruded. A square wave signal at a frequency of 100 Hz and with a peak-to-peak amplitude of 5 V was applied to the first pin. The second and fourth pins were connected together to ground and the third pin to an electrometer. The output from the electrometer was connected to one channel of a dual beam storage oscilloscope. The other channel of the oscilloscope displayed the square wave input to pin 1 of the electrode.

Surgical needles in the electrode constructed for our experiments are 0.64 mm in diameter above the tapering point. Before securing the four needles in a fixed position by embedding them in clear plastic, we confirmed Zaerr's observation that minor differences in needle spacing had no effect on shape of the oscilloscope trace obtained from plant tissue. There was, however, a slight increase in peak-to-peak amplitude when needles were more closely spaced.

The needles of the electrode are embedded in plastic at a spacing of about 7 mm (fig. 4). Two 4-foot coaxial cables (RG-58 A/u) are used to connect the electrode needles to the signal generator and oscilloscope (fig. 12). Needle 1 is connected to the output terminal of the square wave generator, needle 3 is connected to the oscilloscope vertical input terminal, and needles 2 and 4 are connected to ground. Needles 2 and 4 are connected together with a short piece of hookup wire.

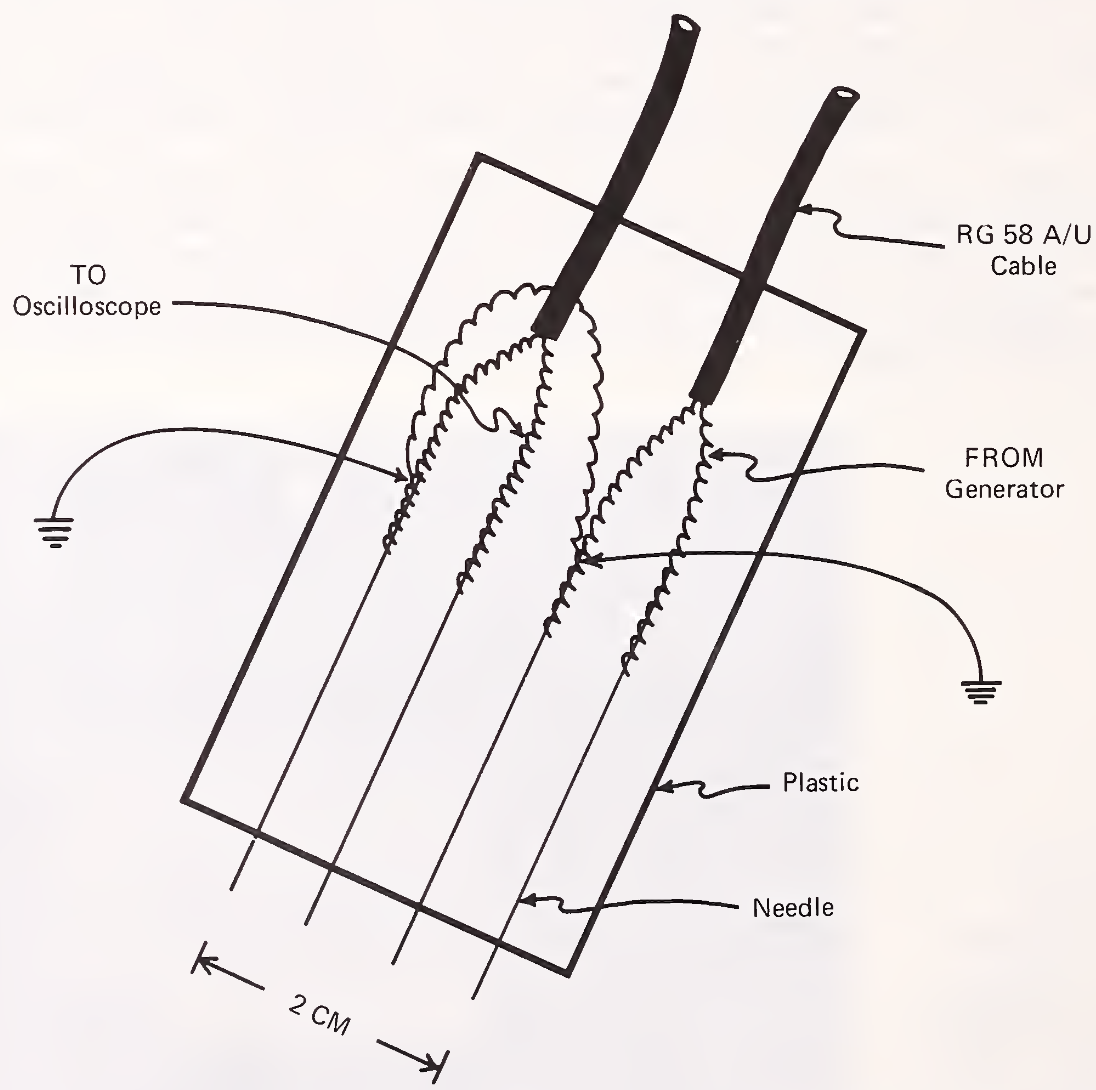


Figure 12.--Schematic illustrating electrical connections used in constructing the electrode.

U.S. GOVERNMENT PRINTING OFFICE: 1975—677-328 / 27 REGION NO.8

Ferguson, Robert B., Russell A. Ryker, and Edward D. Ballard
1975. Portable oscilloscope technique for detecting dormancy in nursery stock. USDA For. Serv. Gen. Tech. Rep. INT-26, 16 p., 7 ref. (Intermountain Forest & Range Experiment Station, Ogden, Utah 84401.)

This report describes the use of a portable oscilloscope and square wave generator system for determining the physiological activity of nursery stock. Observations on a number of tree and shrub species throughout all seasons of the year are presented, and additional potential uses for the technique are suggested.

OXFORD: 161, 165.622, 232.32, 232.41.
KEYWORDS: planting stock, dormancy, plant physiology, oscilloscope, nursery methods.

Ferguson, Robert B., Russell A. Ryker, and Edward D. Ballard
1975. Portable oscilloscope technique for detecting dormancy in nursery stock. USDA For. Serv. Gen. Tech. Rep. INT-26, 16 p., 7 ref. (Intermountain Forest & Range Experiment Station, Ogden, Utah 84401.)

This report describes the use of a portable oscilloscope and square wave generator system for determining the physiological activity of nursery stock. Observations on a number of tree and shrub species throughout all seasons of the year are presented, and additional potential uses for the technique are suggested.

OXFORD: 161, 165.622, 232.32, 232.41.
KEYWORDS: planting stock, dormancy, plant physiology, oscilloscope, nursery methods.

Ferguson, Robert B., Russell A. Ryker, and Edward D. Ballard
1975. Portable oscilloscope technique for detecting dormancy in nursery stock. USDA For. Serv. Gen. Tech. Rep. INT-26, 16 p., 7 ref. (Intermountain Forest & Range Experiment Station, Ogden, Utah 84401.)

This report describes the use of a portable oscilloscope and square wave generator system for determining the physiological activity of nursery stock. Observations on a number of tree and shrub species throughout all seasons of the year are presented, and additional potential uses for the technique are suggested.

OXFORD: 161, 165.622, 232.32, 232.41.
KEYWORDS: planting stock, dormancy, plant physiology, oscilloscope, nursery methods.

Ferguson, Robert B., Russell A. Ryker, and Edward D. Ballard
1975. Portable oscilloscope technique for detecting dormancy in nursery stock. USDA For. Serv. Gen. Tech. Rep. INT-26, 16 p., 7 ref. (Intermountain Forest & Range Experiment Station, Ogden, Utah 84401.)

This report describes the use of a portable oscilloscope and square wave generator system for determining the physiological activity of nursery stock. Observations on a number of tree and shrub species throughout all seasons of the year are presented, and additional potential uses for the technique are suggested.

OXFORD: 161, 165.622, 232.32, 232.41.
KEYWORDS: planting stock, dormancy, plant physiology, oscilloscope, nursery methods.

Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field programs and research work units are maintained in:

- Billings, Montana
- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)
- Reno, Nevada (in cooperation with the University of Nevada)

AMERICAN REVOLUTION BICENTENNIAL
1776-1976

GROWING FROM '76
U.S. FORESTRY CENTENNIAL